# Vertical Spinner Ant-weight Battlebot

Team #21
Andrew Bajek, Elise Chiang, Giovanni Escamilla

TA: Jiaming Xu

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# Contents

# 1. Introduction

### 1.1 Problem

The Antweight 3D Printed Battlebots Competition entails up to eight battlebots competing in a bracket to determine which can outperform the rest. In order to compete in the competition, our robot must meet specific requirements including but not limited to: a maximum weight of 2 lbs; 3D-printed using PET, PETG, ABS, or PLA, PLA+; controlled using Bluetooth or Wifi; and the inclusion of a custom PCB. The custom PCB will house the microcontroller, Bluetooth or Wifi receiver, h-bridge, and additional sensors. The battlebot should be able to tolerate extreme mechanical stress from other bots while also being able to deliver damage using a weapon.

### 1.2 Solution

Our solution is a robot with a two-wheel drive and vertical drum spinner weapon. The robot will consist of four subsystems: power, drive, weapon, and control. Our custom PCB will contain an STM32WB series microcontroller which will control the weapon and drive subsystems while also monitoring electrical and mechanical stress to limit damage to the robot. The microcontroller will also connect to a PC using Bluetooth to remotely control the battlebot. The exterior of the battlebot will be 3D printed using PLA+, a flexible and durable filament.

### 1.3 Visual Aid

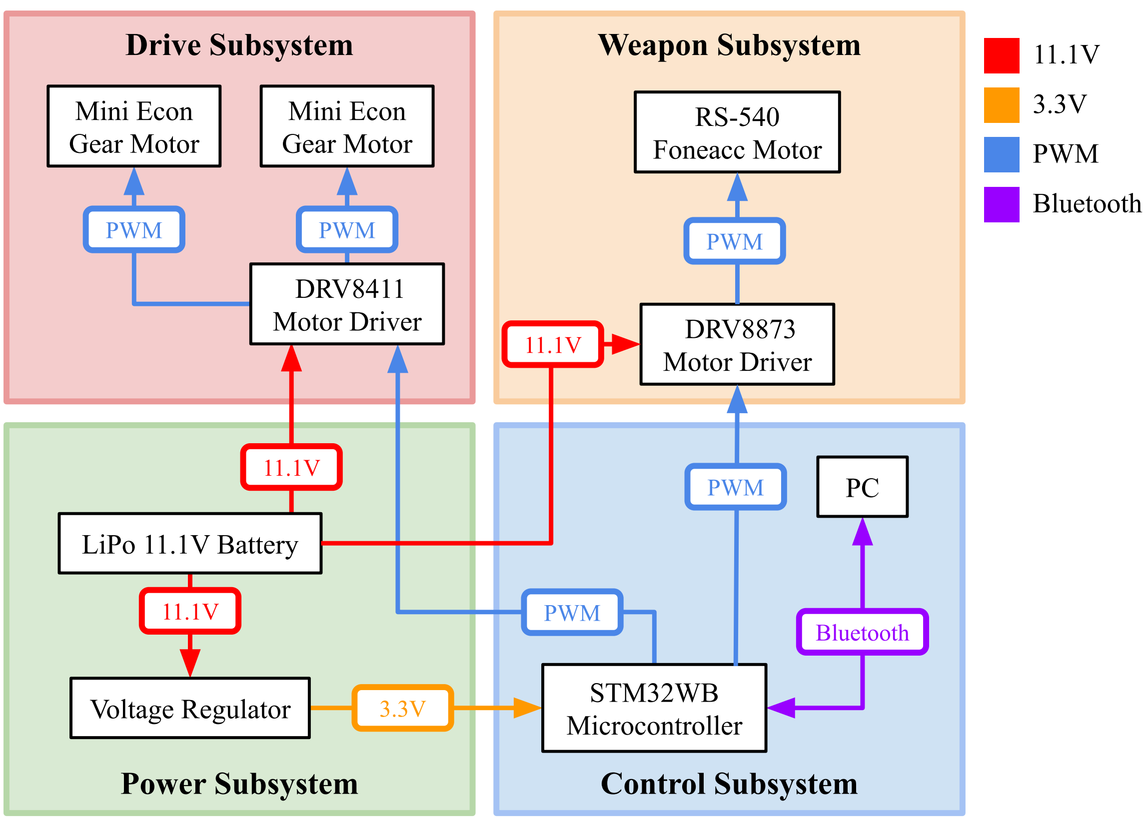

*An example of a vertical spinner robot that would have a drum-like weapon.*

### 1.4 High-level Requirements List

- **Mobility**: Given that the arena itself is only 10' by 10' top speed is not our main concern. Our area of control in the field will be our main focus rather than our speed, causing us to lean more towards a max speed near 1.5 meters per second.
- **Latency**: Our control in the field requires us to have as little latency as possible. In the ideal world, we are aiming towards a latency near 50ms, however, our minimum requirement is near 250ms.
- **Weapon Speed**: A large portion of our bot's weight will be in our weapon itself. This weight distribution will cause our bot to have harder control while our weapon spins. This issue will be worsened with faster spinning speeds from our weapon, however a higher weapon speed will allow for higher damage. Overall we are still leaning for a weapon speed near 11 meters per second for good damage and control in the field.

# 2. Design

### 2.1 Block Diagram



### 2.2 Subsystem Overview

- **Power**: Our power system will supply the robots' entire energy. For this system, we just need to maintain a constant output voltage for the entirety of the two minute fight. From our current LiPo 11.1V battery needs to be able to power our three motors. Two motors control our drive and one controls our weapon. We also need to power our control system through our STM32WB series microcontroller. Our power system will then require some voltage regulation that we will design into our PCB.

- **Drive**: The drive subsystem will consist of two wheels driven by one DC motor each to allow us to control the movement of the battlebot. We chose 508 RPM Mini Econ Gear Motors which are lightweight, rotate at up to 508 RPM, and provide up to 2.4 kgf-cm of torque. These specifications will provide enough mechanical power to move the robot quickly and precisely. The motors will be driven by a DRV8411 Dual H-Bridge Motor Driver which inputs four PWM signals from the microcontroller to drive the motors at different speeds. Additionally, the DRV8411 driver implements current regulation to reduce current spikes during motor startup and stall conditions.

- **Weapon**: The subsystem for the weapon will consist of a 3D printed medium solid drum that spins vertically to attack opponents. The motor we chose for the weapon is the RS-540 Carbon Brushed Micro DC Motor. This motor is about Φ 1.409 inch * 1.97 inch for dimensions, 0.5 Kgf·cm for torque, 160g for weight, and can spin up to 15,300 RPM with the weapon on. These characteristics will provide our weapon to deal significant damage in the arena. The motor will be driven by a DRV8873 H-Bridge Motor Driver to provide PWM control from the microcontroller as well as regulating current from the motor stalling.

- **Control**: The control system is centered around our STM32WB series microcontroller, which will connect to our PC wirelessly through bluetooth. It will be powered by a regulated voltage at 3.3V. Our microcontroller will monitor and control all motors in our robot and have an additional sensor around the weapon control to make sure that we don't over stress the motor to the point of damaging our own drum spinner.

### 2.3 Subsystem Requirements

- **Power**:
  - Our power source must be able to continuously power our bot for the duration of 3 minutes.
  - A voltage regulator must consistently drop our voltage from our source from our peak 11.1v to near 3.3v.

- Currently needs to power three separate systems continuously. These systems all require separate continuous power.
- The robot will have an LED that is easily visible from the outside of the robot to indicate that power is on.
- The PCB must incorporate some circuitry to prevent the battery cell voltage from decaying below 3.0V/cell or exceeding 4.2V/cell.

- **Drive**:
  - Each motor should rotate at 508 RPM under no load and at least 400 RPM under load.
  - The DRV8411 will limit large currents (>1.4A) during motor startup and stall conditions to protect the motors by comparing the voltage across a sense resistor to an internal reference voltage.
  - If we use 3” diameter wheels, at a rotational speed of 400 RPM, the battlebot should be able to move at:

    $$v = 2\pi r * \omega/60 = 2\pi * (1.5 * 0.0254) * 400/60 = 1.60\ [m/s]$$

    This is sufficient to meet the high-level goal of a 1.5 m/s movement speed.

- **Weapon**:
  - The motor should operate around the no load threshold of 17.8k RPM. When the weapon is mounted, the motor should rotate around 8k - 13k RPM.
  - The vertical spinner will be below the 5 inches of the arena wall.
  - The weapon will have to come to a full stop within 60 seconds of the power being removed using a self-contained braking system.
  - If the weapon has dimensions of 45 mm diameter, 80 mm length, and the motor working at 5000 RPM, The weapon should be able to move at:

    $$v = 2\pi r * \omega/60 = 2\pi * .0225 * 5000/60 = 11.78\ [m/s] = 26.35\text{mph}$$

- **Control**:
  - STM32WB series microcontroller need to be able to wirelessly connect to our PC via Bluetooth.
  - STM32WB series microcontroller needs to be powered between an interval of 3-3.6v with the target voltage being 3.3v.
  - Our control system will require a max power of near 500 mA to keep control of all the other systems.
  - Needs to be able to connect wirelessly while inside our competition box meaning a band near 2.4 GHz from our bluetooth connection.
  - Operate for more than 3 minutes to ensure that we can operate during the competition.

- Needs to be able to hold accurate sensing information and logic that doesn't act in unintended ways that may sabotage our commands.
- The robot will have an LED that is easily visible from the outside of the robot to indicate operational Bluetooth connection.

## 2.4 Subsystem Testing

- **Power**: Stress test will be needed to see if our battery and motors are able to work in tandem. This will require our motors to be given full power with an accurate load during the competition. We will also increase load dramatically to test peak power limitation to simulate conditions that we will face during the competitions. A continuous stress from a natural load will also have to be tested for around 3 minutes to see if we are able to easily operate for the total 2 minutes. Additional tests would also be continuous with several increases in load demand to simulate fighting conditions.

- **Drive**: We will test the drive subsystem by using a torque sensor under zero load and load conditions. We will also use a current probe to measure the startup and stall currents to ensure they don't exceed 1.4A. Finally, we will test the linear speed by timing the bot as it travels across a set distance.

- **Weapon**: Similar to the drive subsystem, we will test the weapon subsystem with torque sensors under both zero and load conditions. Additionally, we will test the current stalls and startups with current probes to make sure they do not exceed 8.7 A. Lastly, we will make sure that the weapon can stop spinning within 60 seconds.

- **Control**: The control system will be tested via a simple barrier test to make sure that communication between Microcontroller and PC isn't interrupted by the competition's safety barrier. Latency will also have to be tested during this to make sure barriers don't increase pause between command and action. Additional testing will be done to make sure that our control will work even if our PC isn't necessarily connected to wifi if our competition swaps to a more isolated location that has low connectivity.

## 2.5 Tolerance Analysis

The LiPo 11.1V battery must be able to supply enough current for the three motors during normal load conditions and worst case conditions. The battery supplies 2000 mAh of capacity at a voltage of 11.1V. With a capacity rating of 40C, the battery can supply up to 88A of current.

$$2.2\ [Ah]\ *\ 40C\ =\ 88A$$

Under normal load conditions, the 508 RPM Mini Econ Gear Motors draw a 0.3A current each. During stall conditions, the motors can draw up to 1.4A each.

The weapon motor can draw up to 8.7 A for the single motor which is pretty significant compared to the other ones, but we are trying to give far more power to our hits than in our drive. However, the normal draw current 1.6 with a standard load given.

With our microcontroller we are at max going to pull near 500mA, but at the majority of the time we will see that our pull be closer to 300mA.

Considering these peaks we should have a margin of safety near 7.33 which keeps us pretty safe from killing our battery.

$$1.4[A]\ *\ 2\ +\ .5[A]\ +\ 8.7[A]\ =\ 12[A]$$

$$88[A]/12[A] = 7.33$$

As it stands we currently need our robot to continuously run for at least 2 minutes, however we want the robot to comfortably handle 3 minutes. With current equipment we are able to easily do this as our battery is able to handle 2000 mAh mix and with the peak demand of 12A we are able to run continuously for 6 whole minutes.

$$(2[Ah]\ *\ 3600[s/h])/\ 12[A]\ =\ 600[s]$$

Overall this just goes to show that our current equipment should be able to handle the demand of the design. We will still have to test these specs to make sure that everything comes out as clean as we predict. Also demands on the field may vary depending on the conditions we are facing, but on average our robot should be able to easily fulfil the wants and needs of this competition.

# 3. Ethics

In order to compete in the battle bot competition, we need to comply with the ethical standards set by IEEE and ACM. In ACM 1.2 and IEEE 1.1, it states that avoiding harm is necessary for professional projects. To maintain this, we will test our robot in approved areas that provide protection against danger from the active weapon. We are also making sure our robot can be turned off manually as well as a shutdown via bluetooth. We will also follow the guidelines laid out by IEEE 1.4 by not taking bribes or participating in unlawful activities. ACM 1.4, 1.6, and 1.7 mentions that we must respect privacy, confidentiality, and other people. Our project will reflect this by following the rules of the Robobrawl competition. This will be done by not using illegal weapons or material to strengthen our robots' durability.

# 4. Safety

### 4.1 Lab Safety

In order to maintain a safe lab environment, we will act in accordance with the lab rules including: maintaining a clean workspace, reporting broken equipment immediately, using appropriate PPE, and always working with a lab partner or partners.

### 4.2 Operational Safety

Battlebots are meant to destroy each other, meaning safe operation is necessary to avoid unintentional damage. In a competition setting, the battlebot will only be powered on in the battle arena. Following each match, we will inspect the robot for electrical and mechanical damage that may cause the bot to malfunction. In a testing environment, we will ensure the robot is in an enclosed area and that all operators and onlookers maintain a safe distance from the bot.

Since we are using a lithium-ion polymer battery, additional safety precautions must be followed. The LiPo 11.1V battery used in this project will be stored in a secure location with insulating material over the terminals to prevent a short circuit. Since cell damage in lithium-ion batteries may result in a chemical fire, we will complete additional fire safety and fire extinguisher training as required by ECE 445. We will include circuitry in our PCB to prevent the battery cell voltage from decaying below 3.0V/cell or exceeding 4.2V/cell. Charge and discharge tests will be conducted with the battery inside a lithium safety bag.

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